Tunable lasers offer the ability to remotely provision wavelengths, deploy all-optical switching and regeneration, and provide restoration to failed optical layers. Also, compared to fixed-wavelength lasers that rely on an intelligent network to switch their signals to termination, tunable lasers ensure that the criteria for switching are inherent in their wavelengths. Here we look at market developments and recent product launches.

Tunable laser market set to surpass US$1bn

A new report "*Tunable Lasers for Optical Communications: Technology, Products, and Applications*" - published jointly by technical consultancy **Sirraya Inc** and fibre-optics market researcher **KMI Corp** (Providence, RI USA; Tel: +1-401-243-8100) - estimates that the annual tunable laser market will soon surpass US$1bn, identifying 26 manufacturers that have tunable-laser products available or in development.

The initially identified use of tunable lasers is for inventory management and sparing. The capability of a tunable laser to adjust to any wavelength means that a network operator only needs to keep one tunable laser for sparing/inventory instead of one laser for each lit wavelength of the network.

Although tunable lasers are more expensive than their fixed-wavelength counterparts, placing a mere 20 lasers in inventory to cover the same requirements of 3,200 lasers has obvious cost benefits for the network operator.

For example, if an operator's desired inventory is 20 lasers for each wavelength, a 160-channel system would require 3,200 fixed-wavelength lasers for inventory. At a typical price of US$1,000, the cost would be US$3.2m for laser inventory alone. Although tunable lasers are more expensive than their fixed-wavelength counterparts, placing a mere 20 lasers in inventory to cover the same requirements of 3,200 lasers has obvious cost benefits for the network operator.

Besides inventory management and sparing, new applications for tunable lasers are emerging as networks evolve. Tunable lasers will improve the efficiency of a variety of functions, including protection and restoration, bandwidth on demand, optical cross-connects, wavelength routing, and next-generation metropolitan area networking.

The report's technology roadmap groups tunable lasers for optical communications applications into three general groups:

• **monolithic-cavity edge-emitter lasers** (13 companies)

The monolithic-cavity edge-emitter family of lasers is based on Fabry-Perot (FP) and distributed feedback (DFB) lasers, with greater integration of device elements such as arrays of DFB cavities or new schemes for integrating distributed Bragg reflectors (DBRs). Advantages include stability, reproducibility, and potential cost efficiencies. However, the integrated nature of these lasers has functionality drawbacks.

• **external-cavity diode lasers** (3 companies)

ECDLs use separate optical components as tuning elements in a hybrid cavity containing a semiconductor gain medium. This category of laser has traditionally been for non-communications applications, but it holds promise as a communications solution if sufficient cost advantages as well as robustness and reliability can be developed.

• **vertical-cavity surface-emitting lasers** (3 companies)

VCSELs have an advantage in that their tunable cavity is short and they can use an FP cavity, resulting in lower-cost solutions. Three companies have VCSELs for the 1550 nm region in various stages of development.

The first generation of DFB lasers were tunable to only 2-4 channels and were of limited use in a network besides being a back-up source in case of failure. However, the new generation of tunable lasers offers tunability to virtually any wavelength within nanoseconds.

ADC Altitun makes a Grating Coupled sample reflector (GCSR), which tunes between 1528 and 1565 nm (suitable for long-haul transmission and EDFA use) as well as a Sampled Grating DBR.

The DBRs produced by ADC Altitun and **Agility** offer much wider tuning bands than their DFB predecessors (e.g. 40 nm) yet offer the least wavelength stability (± 3 GHz). Being able to lock wavelengths within a tiny range of their centre frequency is absolutely crucial in DWDM applications. Wavelengths must lock within 5 GHz of the centre frequency for 100 GHz spacing but 1 GHz for 25 GHz spacing.

Agility's DBR (its 3040 Widely Tunable Laser) has a power output of 4 mW (higher than Altitun's) and can be tuned to any of 100 wavelengths in under 10 ms. These two companies are competing on the bases of manufacturability and scalability. Both processes are complex, although Agility's involves a slightly simpler process.

However, fixed-wavelength VCSELs quickly consumed virtually the entire market for short-reach applications due to their ability to deliver better performance at a lower cost. They emit narrow linewidths, consume less power and can be tuned simply by altering the length of the vertical cavity in which the laser is produced.

But VCSELs could only be used for short transmission distances before the availability of lasers that operate at 1310 and 1550 nm bands.

The advantage offered by VCSELs for LANs will likely become equivalent for the WAN and the MAN as soon as Nortel Networks can produce a competitive product. However, its current idea of incorporating a 1310 nm pump laser inverts the cost advantage and simplicity of the VCSEL.

The market for VCSELs in the short-haul space was US$262m in 1999 and should grow to US$3.4bn by 2004 on the back of the robust fibre-channel and storage-area network build-out, in addition to the introduction of Very Short Range (VSR) SONet (a market expected to reach US$3.7bn by 2009).

New Focus and **iolon** may have the competitive edge in tunables now that the formerly lab-bound method can be fitted onto telecom transmitter cards. With 20 mW of power output, aside from the narrow-tuning DBRs from **JDS Uniphase** and Lucent's **Agere Systems**, no other laser comes close. With the ability to tune to any transmission band, they could be deployed for interconnection points in all-optical DWDM network.

Tunable laser market US$50m in 2001

According to a **Yankee Group** report "*Stay Tuned for Tunable Laser*" (www.yankeegroup.com), the tunable laser market will grow from US$50m in 2001 to US$2.32bn in 2005.

Tunable lasers are aimed at intelligent, next-generation optical networks built to address future applications including bandwidth-on-demand.

This capability will make it possible to isolate, route and manage individual wavelengths to serve customer-specific traffic and services in line with demand. Tunable lasers will alleviate costly inventory management associated with fixed-wavelength lasers, reducing operational cost and complexity.

"Tunable lasers are emerging as a solution that will reduce the number of unique lasers needed, while taking DWDM and switching systems to the next level of network flexibility."

Tunable lasers reduce the complexity and costs of networks while capitalizing on dynamic bandwidth requirements.

Whereas current lasers operate at fixed frequencies, requiring at least one spare unit for every channel operating in the network, tunable lasers substantially decrease the amount of spares required for the network. Ultimately, tunable lasers reduce capital investment for spares, space requirements and logistical problems, and also enable remote software provisioning.

"There is immediate application for these lasers in reducing inventory and associated costs," said research analyst Elizabeth Bruce. "Beyond initial sparing-applications tunable lasers will ultimately be used to enable flexibility in optical networks, allowing dynamic provisioning of bandwidth and wavelength routing."

Tunable lasers increase network value by increasing network agility and laying the groundwork for next-generation optical services and packet switching.

"The tunable laser will allow the network operators to save substantial amount as the number of channels grow and offer them the flexibility, which is of the paramount for the next generation networks," says senior analyst Jay Patel.

Table. Companies developing or manufacturing the various types of tunable laser (source: KMI Corp/Sirraya Inc).

Monolithic cavity

ADC Altitun
Agere
Agility
Alcatel Optronics
ExceLight
Fujitsu
JDS Uniphase
Marconi Optical Components
Multiplex
NEC
NEL
Nortel Networks
Santur

ECDL

Blue Sky Research
iolon
New Focus

VCSEL

Bandwidth9
Novalux
Princeton Optronics